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Urban River Pollution Control and Remediation

J. Wang [a], X.D. Liu [b], J. Lu[a*]

[a]*Department of Resources and Environmental Engineering, Shandong University of Technology, Zibo 255049, P. R. China*
[b]*Zibo Environmental Monitoring Center, Zibo 255000, P. R. China*

Abstract

As an important subsystem of urban environment, urban river offers many kinds of ecological services which benefit the city dwellers. However, with the acceleration of urbanization and rapid development of economy, urban river pollution problem are becoming more and more critical. This paper described the current situation of urban river pollution, summarized the researches on river pollution control and remediation. After compared and analyzed different techniques and clarified the concepts of bioremediation technology, based on the advances of river remediation, this paper concluded the approaches to alleviate the river pollution problem that the biological-ecological remediation should be utilized as the primary technique, and the physical and chemical remediation as the supplementary means.

Keywords: River pollution control; Physical remediation; Chemical remediation; Bioremediation

1. Introduction

With the rapid development of economy and the acceleration of urbanization, the river pollution occurred continuously, which results in the river ecosystems damaged seriously. Vast quantities of domestic and industrial wastewater flowed into the river, which leads to the water system become severely polluted. Accordingly, the function of river as resources was lost and the urban ecology and water environment are seriously deteriorated. The problems of urban river pollution and ecological damage are becoming more and more critical. According to the statistics, by the early 20th century, there

* Corresponding author. Tel.: +86-533-2787337; fax: +86-533-2783397.
E-mail address: lujied@126.com.

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is not almost a complete natural river in the world [1]. Therefore, it is urgent to develop a cost effective technique to manage the river water quality.

2. Physical Remediation

2.1. Aeration

Aeration can restore and enhance the growth and the vitality of micro-organisms to improve the water quality. The aeration technology is a simple and effective method which began to be utilized since the early river restoration. In practical applications, many factors should be taken into account, such as channel conditions, source characteristics, water quality improvement requirements, etc. and the fixed aeration, mobile aeration and water aeration are selected limberly when it can be achieved to deal with the sudden pollution for improving water quality over a short period. Since the 1960s, the mobile oxygenation platform was used as well as the fixed aeration station in the river aeration, which was the common method and was applied in some countries [2].

Presently, the utility of river aeration technology has relatively been mature in foreign countries, and the research and practical applications showed that the artificial aeration can improve water quality effectively. The river aeration technology has been used successfully in the treatment of the Oeiras River in Portugal, the Emsche River in Germany, Thames River in UK and Homewood Canal in U.S. [3]. The aeration equipment was utilized in the treatment of the Homewood Canal of U.S. in 1989, which increased the dissolved oxygen in bottom water and by which the biomass of river became enriched. The river aeration was used to improve the river water quality effectively in Germany in 1994. The river aeration technology was used to eliminate the phenomenon of black-odor of water thoroughly in Busan, South Korea.

In order to improve the environment, eight aeration equipments were placed in Qing River with each power of 11.025 KW during Beijing Asian Games as early as 1990, which made the level of dissolved oxygen rose from 0 to 6mg/L, and the removal rate of BOD_5 also reached 60%. This process almost eliminated all odors in the river. Shanghai Academy of Environmental Sciences set some aeration points in the river channel to conduct the experiment of water aeration and bioremediation. In this experiment, the dissolved oxygen level of the water body which was in anaerobic condition originally increased significantly, and the growth of the indigenous aerobic microorganisms was stimulated greatly, and the removal rate of organic pollutants in water was up to 10.7% ～ 23%. The concentration of BOD_5 and NH_4^+-N decreased by 2.492mg/L, 1.217 mg/L and 0.322 mg/L after aeration in the Guancheng downstream section of the Dongguan Canal. Wang Chengxin and his group conducted a pilot study on aeration in Shanghai Suzhou River by using BIO method. The results showed that the pure oxygen aeration could reduce the COD_{cr} of the black-odor water and the removal rate could reach from 19.5% to 56% [4].

2.2. Water Diversion to Flush Out Pollutants

It is feasible to control river pollution through water diversion. The clean water could dilute polluted rivers, which results in the black and stink of water body eliminate quickly, the self-purification capacity of water body improved. The water diversion to flush out pollutants was used in Fuzhou, Zhongshan and other cities in China, while the calculation of diversion scale was the key technology based on the effluent water quality. For example, Hong Lijian analyzed the effect of flushing out pollutants of diversion scale about Fuzhou River, which was applied to engineering design [5]. But the project of water diversion to flush out pollutants was large and the cost was relatively high.

2.3. Sediment Dredging

The different dredging methods would produce different environmental effects. Generally, the extensive operation way of grab or drag-suction dredger will cause resuspension of sediment [6]. The water injection dredging was a kind of sediment dredging method in situ, which could improve efficiency and reduce cost, and this approach was adopted in the sediment dredging of UK port channel and Xuan Wu Lake in China [7]. The most advanced type of environmental dredging is the cutter suction dredger currently, and such dredging boat equipped with the automatic control and monitoring systems to improve dredging accuracy greatly, which was used in the Wu Li Lake, Chao Lake in Anhui and Dianchi Lake in Kunming in China to dredge sediment [8].

3. Chemical Remediation

3.1. Flocculation and Sedimentation

The flocculation and sedimentation method could be used to the water treatment with a large number of suspended solids and algae, which was simple to operate, easy to maintain and effective to treat, however, the infrastructure costs and pharmacy costs were high, meanwhile, it was associated with secondary pollution. Therefore, it cooperated with other processes as a pretreatment process. The flocculation foam separation of poly aluminum chloride (PAC) and casein was non-polluting, which was for recovery and removal of algae, and the best agent injection conditions were that the concentration of PAC was 5mg/L, the time of rapid mixing was 3min, the concentration of casein was 15mg/L, and pH=7-8 [9].

3.2. Removal of Algae by Chemical Agent

The commonly used chemical agent for algae removal were copper sulphate, bleaching powder, alum, poly aluminum and ferrous sulfate, etc.. It could remove the algae effectively and reduce or even eliminate the smell of water to put the copper sulfate and change the value of water PH; the calcium hypochlorite can kill the green algae, cyanobacteria and diatoms causing the water bloom effectively. The experimental research on the treatment of cyanobacterial bloom based on chemical algicide with main ingredient of acetic acid was carried out in Xuanwu Lake in Nanjing in 2005, and the total algae of the experimental area reduced by 82.8% after treatment [10].

4. Bioremediation Technologies

In the bioremediation process, indigenous or cultivated microbes and other organisms are used to transform the poisonous and harmful pollutants to non-toxic substances under the controllable environment. The bioremediation was firstly used to eliminate the gasoline pipeline leak in Pennsylvania in 1972. The bioremediation technology, playing a significant role as the main means, was likely the first large-scale application at this time, which was a milestone in the development of bioremediation, and attracted more and more attention [11].

According to the degree of human intervention, the bioremediation could be divided into natural and artificial bioremediation, and the latter could be divided into in-situ bioremediation and ex-situ bioremediation. On the one hand, the in-situ bioremediation means to use bioremediation technology directly in polluted rivers without any pollutant excavated and transported. In this process, indigenous microbes which sometimes combine with domesticated microbes are used. In addition, it usually needs

various measures to strengthen the technology effect. On the other hand, the ex-situ bioremediation was that the polluted water was taken out from the contaminated areas to be treated after transportation. Therefore, as engineering technology for river pollution controlling, the bioremediation was advanced rapidly from 1990. There are many advantages for the bioremediation technology, such as reduced cost, low environmental influence, no secondary pollution or pollutant movement, reducing pollutant concentration by the maximum extent, available for the sites where regular pollution treatment technology is difficult to be applied, and so on. The bioremediation technology is the most promising remediation.

4.1. Remediation Technology with Aquatic Plants

Plants have a certain degree of purification for water pollution, especially aquatic plants. The plants with strong absorption for pollutants and good tolerance could be planted in the polluted water. Accordingly water pollutants were removed or fixed through adsorption, absorption, accumulation and degradation by the plants for water purification. The plants for restoration commonly used Reed, E. crassipes(water hyacinth), cattail, A. philoxeroides, etc [12].

Based on the laboratory and simulation experiments, Guo Changcheng and his group proved that the potamogeton had good purification effect for the polluted river water from the sewage of inferior Ⅴ class mainly in the dry fall and winter. Tong Changhua used aquatic plants to control the pollution of eutrophicated water [13]. The results showed that aquatic plants had a higher ability to remove TN, TP and nitrate nitrogen. Among them, foxtail alga and grain leaf pondweed could effectively remove TN (83.84% and 77.54%), TP (91.3%) and nitrate nitrogen (95.85% and 90.65%), but had no significant effect on removing ammonia nitrogen (only 14% to 70%).

4.2. Remediation Technology with Aquatic Animals

The aquatic animals were used to remediate the water of eutrophication abroad, and adjust the structure of water nutrition through changing the composition and density of fish. The use of silver carp, common carp and other filter-feeding fish could control the eutrophication caused by phytoplankton (algae) effectively.

4.3. Microbial Remediation Technology

4.3.1. Bio-film Technology

The bio-film technology utilizes biomembrane attached to the natural river bed and micro-carrier to move the pollutants in the river through adsorption, degradation and filtration under the conditions of artificial aeration or dissolved oxygen. The bio-film was studied in the United States, Germany, Japan, Britain, France and other countries largely, and John E, Hermanowicz, Xinmin, Yang and other people [12-14] considered that the structure of bio-film was affected by various external conditions which were water conditions and the composition of substrate.

The bio-film technology for river purification in Japan and South Korea and other countries were gravel contact oxidation method, artificial packing contact oxidation method, thin layer flow method, underground stream purification method, etc. The strengthening purification technology of river researched by Japanese were mainly indirect purification, which was to build the purification facilities on the side of the river, using the drop of the river to lead the water into the purification facilities and purify before discharging. By the way the purification facilities mostly use the underground model in order to

save space. Japan Nogawa utilized the gravel contact oxidation, the packing was gravel, and the removal rates of BOD and SS were 72.3% and 84.9% respectively. With new non-woven fabric as packing, the drainage ditch facilities in Chiba County was set on the side of the ditch, and the removal efficiency of SS reached 97%, the removal rates of BOD and COD were 88% and 70% respectively [15]. Park, Y. K. utilized UF-ozone-biological activated carbon to filter and purify the polluted Kumbo River, and the removal rate of ammonia reached 90%, the removal rate of TOC was significant [16].

Bio-ceramics were used as the carrier to treat a polluted river in Shenzhen, and the average removal rates of NO_2- N, NO_3- N, COD, turbidity, color, Mn and alga were 90.8%, 84%, 21.4%, 62%, 47%, 89% and 68% respectively[17]. Based on the use of sewage treatment technology by rubber packing inner loop fluidized bed bio-film, the average removal rates of COD and ammonia were 88.16% and 91.8%, and the highest removal rates were 94.64% and 94.08% respectively. Wang Shu mei installed aerators, bio-film and added special bacteria in the river, and the removal rates of COD_{Cr}、BOD_5、NH_4^+-N、TN、TP and SS were 67.4%、87.7%、34.3%、30.3%、53.3% and 39.7%, the dissolved oxygen and transparency in the river increased from 0.9 mg/L and 12.5cm to 7.6 mg/L and 137.5cm respectively [18]. Yang Tao laid the biological filter media on the river surface, and the average removal rates of COD, ammonia nitrogen and total phosphorus were 40.00%, 36.43% and 43.02% respectively [19].

Lei Jin yong simulated the polluted river with main sewage, and used the composite packing of pebbles and zeolite for bio-film formation, which got good results in terms of degradation of organic matter and ammonia and nitrogen, etc. [20]. Wang Xuejiang used TX-type cylindrical suspended carrier whose density approximately equal to water to purify the tributary of Suzhou river, and the method was suitable for the transformation process of biological aeration treatment of sewage on the river directly [21]. Based on the structural modification and flowing optimization of suspended-carrier reactor which developed by themselves, Wang Rongchang applied it to the in-situ remediation of the water quality of polluted river [22]. The use of biological streamer treatment technology to construct sewage treatment scattered facilities in the river achieved the purpose of eliminating the black-odor of the water, and the bio-ribbon technology has been applied in the New Island Creek successfully [23]. Xiao Yutang and his group used the biological contact oxidation in the pretreatment of the micro-polluted raw water of Yao Jiang, and the bio-film thickness of the water was 0.3-0.5mm, the effluent was 0.1-0.3mm, when the dissolved oxygen of the water was controlled in 7-9mg/L, the bio-film of the filler was full of aerobic layer with high aerobic oligotrophic microorganisms mainly [24]. Biological contact oxidation of flexible three-dimensional packing and oxygen-rich microporous aeration were used to repair the polluted Chuan Yang River of Shanghai. It is observed that the biofacies were rich on the bio-film, with small thickness, the biodegradation rate of ammonia and nitrogen of pollutants was high, and the aerobic bio-film of packing has played the main role to remove the pollutants [25].

4.3.2. Microorganism Dosing

This technology uses specific and efficient microorganism to decompose, transform, absorb the pollutant in the water, to purify quality of the river by sifting of the efficient microorganism, optimized construction of the microorganism, extensive training and putting in, etc. The construction of highly effective compound bacteria was the key step to determine the effect in the process of microorganism dosing. At the present time, it was studied and applied in the purification of sewage, industrial waste water, and the water of eutrophication. FLO-1200 achieved remarkable results in the river pollution control under the conditions of river aeration [26]. Zhang Li added bio-energizer, combined water mixing and strengthened the ability of microbial degradation artificially for water purification [27].

5. Development Trend

The research and application of river control technology in foreign countries began with Japan, the United States and some European countries in the 50s of 20th century. Their concept of river management was the comprehensive control from the ecological protection and environmental governance, and combined the engineering measures with water environment and social environment. The river eco-restoration became an international hot spot after 1980s. China has entered the stage of comprehensive river control and eco-restoration in the late 1990s, and has carried out much remediation work. But most of them remain in the initial experiment. Proposals on the trend of river pollution remediation are finally put forward.

- To achieve health and sustainable development of the river ecosystem, the river should be treated by bio-eco remediation as priority and the physico-chemical remediation as the assistant means.
- Bioremediation materials should be optimized, and the bioremediation mechanism is studied from different angles and hierarchical to improve the bioremediation technology further.
- The general applied conditions of various technologies such as aeration, bio-film and microbial preparation and dosing are determined.
- The appropriate microorganisms are acclimated to adapt to different polluted river.
- The river pollution control technique for urban area should be researched and studied.

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